MODIS DATA STUDY
TEAM PRESENTATION

October 19, 1990

AGENDA

1. Action Items
2. Plan for Response to the Action Item 10/5/90-2
3. Earth Models
4. Some Additional Issues Relating to the MODIS Level-1 Processing Design
5. MODIS Level-1 Processing System Preliminary Design Milestone Chart

ACTION ITEMS

8/10/90-1 [John Barker]: Specify data requirements for the MCST Support Products (at Level-1A and Level-1B). STATUS: Presentation was given at the 9/21 MODIS Data Study Team Meeting. Doug Hoyt has been assigned an Action Item to identify any missing items or issues requiring additional clarification. This Action Item is considered closed.

10/5/90-1 [John Blaisdell]: Contact Dr. Bob Evans at the University of Miami to discuss the Earth shape model that the Oceans Discipline Group would prefer to use in MODIS Level-1 geolocation activities. STATUS: Oral report given at 10/12 MODIS Data Study Team Meeting. Closed.

10/5/90-2 [Doug Hoyt]: Examine MCST documentation and identify missing or additional information items that the MODIS Data Study Team will need to complete the specification of MODIS calibration processing. STATUS: See attached report.

10/12/90-1 [John Blaisdell]: Investigate alternative Earth shape models that are potentially useful for MODIS geolocation activities, investigate typical applications of the various alternatives, determine the names of investigators who use the various models, and generate a written report of findings. STATUS: See attached report.

10/12/90-2 [Watson Gregg]: Prepare a report on MODIS anchor point requirements. Analyze the utility of alternative parameters to describe MODIS observation geometry, the solar illumination, and lunar position (perhaps required for calibration) at each pixel location and determine the specific angular parameters required to completely specify the geometry of each observation. Determine which items are available from sources external to MODIS processing and which items will need to be computed within the MODIS processing. STATUS: Open.

PLAN FOR RESPONSE TO THE ACTION ITEM 10/5/90-2

ITEM: "Examine MCST documentation and identify missing or additional information items that the MODIS Data Study Team will need to complete the specification of MODIS processing."

RESPONSE: The presentation material of Dr. Barker was examined. The MCST material requires further study in regard to the MCST/MSDST interactions and possible impacts of MCST activities on the Level-1A processing, communication, and storage requirements. Listed below under separate major categories are some questions which, when answered, will provide better coordination between MCST and MSDST in the area of data processing. These questions can be answered by the MCST and be used as input to the up-coming document on the Level-1 Processing.

MCST SUPPORT PRODUCTS AND MCST/MSDST INTERACTIONS:

1. Would you please define better the MCST Support Products (e.g., what data?; how frequently will it be requested?; will it all be automatically sent?).

2. Will MCST send calibration coefficients to the DAAC? Will it be done routinely? Or will it be done only for reprocessing?

3. What are the contents and purpose of the "Interface Control Document" planned by MCST? Will a section be devoted to the MCST/MSDST interface?

4. Will MSDST receive copies of all calibration planning documents? What are the titles of these planned documents?

REPROCESSING:

1. How many reprocessings do you anticipate in the activation period?
2. Could you provide a list of scenarios which could lead to a reprocessing of the data?

HARDWARE/SOFTWARE QUESTIONS:

1. Would you supply the MSDST an estimate of the number of floating point operations per pixel required for calibration processing? In other words, what are the MCST CPU requirements?

2. What data block sizes will be required to be stored on-line at the DAAC for calibration purposes? What off-line storage requirements does MCST have?

3. Will the MCST calibration algorithms require the input Level-1A data to be time ordered without missing data before processing starts? For example, could processing for a day begin even if the first several orbits are missing? What other timeliness requirements does MCST have?

4. What computer language(s) does MCST anticipate using for its algorithms?

5. What other hardware or software requirements does MCST have which may impact MSDST activities or the data processing at the DAAC's? For example, are there special communication requirements that MCST requires?

6. Please describe or define the MCST utility products (e.g., the radiometric heterogeneity mask).

7. Please give your thoughts on why Level-1B data should be generated on demand only vs. being generated and archived.

CALIBRATION SCENARIOS:

1. MSDST would benefit if it had calibration scenarios for the cases below. A narrative account giving the time sequence of events would be helpful along with the interactions of the MCST with various EosDIS organizations particularly if they could lead to an impact on the MSDST or the Level-1A processing.

    a. Operational calibrations (e.g., how often are solar diffuser calibrations made and how often are other types of sources viewed?). When will a definitive list of operational modes become available?

    b. Field experiment calibration scenarios (e.g., are buoy observations to be input routinely into the DAAC processing? are White Sands observations to be routinely input?).

    c. Quick-look calibrations (e.g., does this impact the DAAC or is it handled solely by MCST resources?).

    d. Direct broadcast calibration scenario (e.g., how often will this occur?; will Level-1 processing be affected?). Will direct broadcast data ever be used as a TDRSS backup?

2. Will scenarios developed by Kaufman, Evans, or others be given to the MSDST?

EARTH MODELS

There have been many attempts to model the surface of the Earth. For many purposes, a sphere of approximately the correct radius suffices. Applications where accuracy obtained from the sphere is sufficient include map projections of the whole Earth (Reference 1) and most astronomical calculations. For any sort of detailed mapping or Earth location, however, corrections must be made. The largest correction from the sphere is to an oblate spheroid (or ellipsoid), defined by a circular equatorial cross-section and an elliptical polar cross-section. More detailed corrections include terms corresponding to higher spherical harmonics, routinely used in orbit predictions, and non-symmetric terms modeling the geoid (actual sea level) in terms of the reference ellipsoid. Topographic models are then referenced to the geoid. This report summarizes various ellipsoids which have been used in Earth modeling, with some information about the more precise corrections and their magnitudes.

There are only two parameters needed to describe an ellipsoid. Generally, one is the equatorial radius, denoted by a. The other may be given variously as the polar radius, b, the flattening f, defined by

$$f = 1 - b/a$$

or the ellipticity e, defined by

$$e^2 = 2f - f^2$$

The most common in the literature (Reference 1, p. 12) is the inverse flattening $1/f$, which has generally been used as the second defining parameter until recently. (Since 1972, the J_2 parameter discussed below has been the defined parameter, along with higher order terms; the flattening of the reference ellipsoid is then a derived parameter.)

For many years, the needs of mapping and surveying drove the development of improved accuracy. Some initial point was chosen and an ellipsoid was then selected which best fit available surveying data. Because the actual geoid, discussed below, varies somewhat from any ellipsoid chosen as reference, different ellipsoids were used for mapping in different parts of the world. Table 1 (from References 1-4) lists some ellipsoids used for mapping purposes by the U.S. Geological Survey and similar national and international organizations.

The advent of spaceflight required global models, firstly for accurate prediction of orbits, and secondly for reconciliation of the various locally mapped areas. Additional data have resulted in redefinitions of the reference ellipsoid, as well as more refined models of the observed excursions of the geoid from the ellipsoid. It is important to recognize that many published maps are referred to ellipsoids other than the most recent global models, and also to recognize that different spacecraft data will have been processed with different models. If precise coregistration is required, the investigator must recognize that use of the older ellipsoids may result in differences of hundreds of meters in calculated latitudes and longitudes for a ground point (Reference 1, p. 13.)

> Until recently, ellipsoids were only fitted to the Earth's shape over a particular country or continent. The polar axis of the reference ellipsoid for such a region, therefore, normally does not coincide with the axis of the actual Earth, although it is assumed to be parallel. The same applies to the two equatorial planes. The discrepancy between centers is usually a few hundred meters at most. Only satellite-determined coordinate systems, such as the WGS 72 and GRS 80 . . . , are considered geocentric. Ellipsoids for the latter systems represent the entire Earth more accurately than ellipsoids determined from ground measurements, but they do not generally give the "best fit" for a particular region (Reference 1, p. 12).

TABLE 1. Ellipsoid Parameters (References 1-4)

Name	Date	*a* (km)	1/*f*	Use
Airy	1830	6377.5634	299.32	Great Britain
Everest	1830	6377.2763	300.80	South Asia
Bessel	1841	6377.3972	299.32	Central Europe; Chile; Indonesia
Clarke	1866	6378.2064	294.98	North America; Philippines
Clarke	1880	6378.2491	293.46	Most of Africa; France
Hayford	1909	6378.388	297	Widespread
Krasovsky	1940	6378.245	298.3	Soviet Union
Australian	1965	6378.160	298.25	Australia
World Geodetic System (WGS)72	1972	6378.135	298.26	NASA, NOAA, DoD
International Astronomical Union (IAU)	1976	6378.140	298.257	NASA, others
Goddard Earth Model-8 (GEM-8)	1976	6378.145	298.255	NASA Flight Dynamics
Geodetic Reference System (GRS) 80	1980	6378.137	298.257	North America; others
World Geodetic System (WGS) 84	1984	6378.137	298.257	Widespread

A primary purpose of the models "beyond the ellipsoid" is the accurate prediction of satellite orbits. The gravitational potential of the Earth is expanded in a standard form (Reference 5, p. 281) as the sum of spherical harmonics. The coefficients corresponding to Legendre functions P_n which are longitude-independent are termed zonal harmonic coefficients. The coefficients corresponding to associated Legendre functions P_n^m are termed sectoral harmonic coefficients for m = n and tesseral harmonic coefficients otherwise (Reference 2, p. 124). The 1976 IAU system defines values for the zonal harmonic coefficients J_2, J_3, and J_4, describing the variation from a spherical surface, as given in Table 2 (Reference 3):

TABLE 2. IAU Adopted Zonal Harmonics (1976)

J_2	0.00108263
J_3	-0.00000254
J_4	-0.00000161

Additional work at Goddard has led to development of more and more accurate models with higher harmonic terms. The GEM-8 referred to in Table 1 included zonal harmonics up to seventh order and sectoral and tesseral harmonics up to fourth order.

Subsequent fits have been made to generate zonal harmonics through order 21 and tesseral and sectoral harmonics through order 12 (Reference 6). In additional to the gravitational potential, the actual sea surface shape includes a term due to the angular momentum of the Earth, corresponding to a centrifugal force, which can be modeled by altering the even zonal harmonic coefficients slightly (Reference 7). The resulting geoid differs from the reference ellipsoid by a maximum of 105 meters (Reference 2, p. 126).

Corrections "beyond the geoid" are not fully predictable and are not practical in general data processing. Knowledge of their magnitudes may be useful for error analysis, however. Table 3 (Reference 6, p. 7-52) summarizes deviation sources.

TABLE 3. Sea Surface—Geoid Deviation Sources

Source	Typical Magnitude
Sea swell	1 meter
Wind waves	1 meter
Storm surges	10 centimeters
Barotropic depressions	10 centimeters
Currents	1 meter
Tides	1 meter

The geoid thus described models the sea surface. Topographic models defining the land surface are beyond the scope of this report.

REFERENCES

1. Snyder, John P., *Map Projections–A Working Manual*, U.S. Geological Survey Professional Paper 1395, Washington, D.C., U.S. Government Printing Office, 1987.

2. Wertz, James R., ed., *Spacecraft Attitude Determination and Control*, Dordrecht, D. Reidel Publishing Company, 1978.

3. Moritz, H., *Bulletin Géodésique 54*, 1980, p. 395.

4. Ellickson, James K., Marie D. Henry, and C.K. Wong, "Formulation of a Generic Algorithm for Earth Locating Data from NOAA Polar Satellites," NOAA/NESDIS, January 22, 1987.

5. Kaplan, Marshall H., *Modern Spacecraft Dynamics and Control*, New York, John Wiley & Sons, 1976.

6. Goddard Mission Analysis System (GMAS), Operational source code, 1987.

7. Long, A. C., J. O. Cappelari, Jr., C. E. Velez, and A. J. Fuchs, eds., "Goddard Trajectory Determination System (GTDS) Mathematical Theory, Revision 1," GSFC Flight Dynamics Division, FDD/552-89/001, July 1989.

SOME ADDITIONAL ISSUES RELATING TO THE MODIS LEVEL-1 PROCESSING DESIGN

1. **Definition of Processing Granule for Level-1A Products.** Considering that users of the MODIS Level-1A Product are likely to have access to sophisticated data processing capabilities and are likely to process large volumes of Level-1A data, and considering that geolocation of MODIS data is not planned as a Level-1A activity (first done at Level-1B), it is suggested that the data processing granule for Level-1A might logically be a full orbit of data. Processing (and storing) full orbits of Level-1A Product might facilitate the transfer of large volumes of instrument data to users who have facilities to subset the data themselves, if required, and it avoids the perhaps unnecessary requirement to assign an Earth location to smaller segments (scenes) of data at the -1A level of processing.

   According to the current (September 14, 1990) preliminary version of the EOSDIS specification, a number of EOS instruments are expected to process and store data by full orbits, so it appears that the introduction of full orbit granules for MODIS Level-1A data would not introduce additional complexity at the DADS where the product will be stored and retrieved. A full orbit of data would be about 4.7 GB for MODIS-N and about 1.1 GB for MODIS-T [Corresponding data volumes for scenes (237.5 seconds) would be about 264 MB and 80 MB, respectively, under daytime conditions]. Distribution media would have to accommodate these minimum data volumes of Level-1A data. Also MODIS Level-1 processing software would be made somewhat more complicated by this option since data would be aggregated by orbit at Level-1A and by scene at Level-1B, requiring two distinct sets of data aggregation and control software.

2. **Product Generation Methodology.** It appears that a "filled-structure" approach would facilitate the generation of Level-1A and -1B products. By a "filled-structure" approach, we mean that the output data structure for an entire processing granule (orbit (?) for Level-1A and scene for Level-1B) is defined and allocated at the beginning of processing for that granule. Completed items are placed in the defined structure as they are completed during processing. Header information for the output product that is extracted from input headers (items in the -1B header that are extracted from the -1A header, say) would be placed in the output headers as the new headers are generated. Data fields would initially be set to an invalid condition, and the invalid condition indicators would be replaced or removed as valid data items become available. The data structure itself need not be rigid; it could include run-length or higher-order encoding. Run-length encoding includes a data type indicator, a length indicator for the field to follow, and the actual data field itself. An example of higher-order techniques might be the use of location pointers rather than the actual data itself in the defined data structures.

3. **Header Structure and "Derived" Data Products.** It appears that most Metadata items used by the IMS and the data user to select and distribute products are also essential items for internal data system use and could be permanently attached to the data granules to which they apply [see the attached list of potential Metadata items taken from the

current EOSDIS specification]. This might be done by defining a "Metadata Section" in the granule header that contains a verbatim copy of the Metadata for that granule. The header could serve as the permanent record of that Metadata item and distributed products derived from the header could be discarded by the IMS or other Metadata recipient without affecting data integrity. Defining a "Metadata Section" of the header would facilitate the "stripping out" of the Metadata for the generation of stand-alone Metadata products. If MODIS Science Team Members require a DQA-Report Product to monitor the quality of their operationally-generated products, a similar approach might be followed for the DQA-Reports, i.e. the header might contain a "DQA-Report" section containing the results of Science Team Member defined DQA tests for that processing granule. DQA-Reports could again be "stripped out" as needed for distribution. At the moment, it is not clear whether a similar approach could be followed for MCST Support Products.

Table C-10: Baseline Core Meta Data Attributes

Fieldname	Bytes	Description
Algorithm Version Number	80	Version number & algorithm name
Archive ID	14	Archive location identifier
Coverage	100	Rect,circular, or elliptical coordinates
Data Type	10	Data type (ancillary, housekeeping,etc)
Footprint	2	Bounding shape (rect,elliptical,circ)
Geographic Location Keywords	20	Continent, ocean, or global location
Granule ID	16	Granule Identifier
Investigator	32	Investigator ID
Platform ID	10	Platform on which sensor was located
Processing Level	2	Level of processing
Product Sequence Number	10	Product identifier
Project ID	40	Supported project that collected the data
Sensor ID	10	Sensor which captured data
Start Orbit Number	4	Orbit number at start of data collection
Stop Orbit Number	4	Orbit number at end of data collection
Start Time	7	Date and time data collection started
Stop Time	7	Date and time data collection stopped
Total Bytes	**368**	

The Core Inventory Metadata Attributes are the minimum set of attributes necessary for an inventry entry.

Table C-11: Baseline Data Set Specific Meta Data Attributes

Fieldname	Bytes	Description
Attitude Information	42	Min & max yaw, pitch and roll
Band Quality	80	Indicator of band quality
Cloud Cover	20	Cloud cover by percentage
Data Gap	240	Includes orbit no.,Lat/Long, time span
Data Quality	20	Quality assessment of data granule
Day Night Flag	1	Indicates image obtained day or night
Ephemeris Information	80	
General Comments	240	General remarks
Image Description	80	General comments about image.
Inventory Date	7	Date granule ingested into inventory
Land/Ocean Tag	20	Percentage land/ocean
Latitudional Resolution	6	Latitudinal gridding of the data
Longitudional Resolution	7	Longitudional gridding of the data
Max Geocorrected Latitude	6	Max latitude of the image after geocorrection
Max Geocorrected Longitude	7	Max longitude of the image after geocorrection
Max Satellite Zenith Angle	6	(-90.00 to 90.00)
Max Sun Azimuth	6	Max sun azimuth for the data
Max Sun Zenith	6	Maximum sun elevation above the horizon
Min Geocorrected Latitude	6	Min latitude of the image after geocorrection
Min Geocorrected Longitude	7	Min longitude of the image after geocorrection
Min Satellite Zenith Angle	6	(-90.00 to 90.00)
Min Sun Azimuth	6	Minimum sun azimuth for the data
Min Sun Zenith	6	Minimum sun elevation above the horizon
Number of Bands	4	Number of spectral bands
Number of Data Gaps	4	Number of missing lines in image
Number of Lines	4	Number of lines or scans in the data
Number of Observations	4	Number of observations included in data
Number of Samples	4	Number of samples or pixels in a line
Operation Mode	80	Description of operation mode
Parameter Information	400	Up to 20 parameters (20 bytes per parameter)
Processing Date	7	Date the product was processed
Processing Location	14	PGS where product processed
Scene ID	10	Input scene Identifier
Start Line From Original	4	Starting line from master scene, if subsetted
Start Pixel From Original	4	Starting pixel from master scene, if subsetted
Storage Medium	4	Storage media
Subset Flag	1	Indicates if the image subsetted from a master
Tilt Angle	5	
Total Data Set Specific	**1454**	
Total Core Metadata	**368**	
Total Inventory Record Size	**1822**	
Daily Granule Count	**21296**	**From Number of Granules Per Day Table**
Inventory Size Per Day (MB)	**74**	**Includes Reprocessing Factor of 2**
Inventory Size Per Year (GB)	**26**	
Mission Inventory Size (GB)	**390**	**15 year mission**

MODIS LEVEL-1 PROCESSING SYSTEM
PRELIMINARY DESIGN

Task 0: Structured Walk Through of Existing Diagrams

Find inconsistencies in the existing diagrams. Understand other workers processing methodologies.

Task 1: Functional Requirements

Using the existing flow diagrams, backsolve for the requirements necessary to perform the processing steps outlined.

Task 1a and 1b: For Level-1A and -1B

Task 2: Data Definitions

Define the data products in a functional manner for the expected Level-0 data, and the output data products (functionally) designated Level-1A and -1B. May also include Level-2 definitions for clarity.

Task 2b: Define data and control items in the environmental model (i.e., MCST, CDOS, ICC, etc.)

Task 3: EOSDIS/MODIS Consistencies

Determine and coordinate any inconsistencies between the EOSDIS SOW specifications and structured diagrams and our MODIS structured diagrams. Use the same types of flow diagrams as the EOSDIS people.

Task 4: MODIS Structured Diagrams, next rev

Split diagrams into context and flow structures. Redefine store items, control items, data items, etc.

Task 4a: Level-1A
Task 4b: Level-1B

Task 5: Data Dictionary, next rev

Add additional information to the data dictionary in both type and content. Discretely define the data dictionary entries.

Task 5a: Level-1A
Task 5b: Level-1B

Task 6a: Event List

Generate an event list of items to be acted upon by the MODIS processing system.

Task 6b: This will lead to a state transaction diagram.
Task 6c: Revisit event list and transaction diagram.

Task 7a: Stores Determination

Determine the type of store items: database, hard copy, sequential records, etc.

Task 7b: Select records fields (functionally) and indexing complexities.

Task 8: Case Tool Selection

Task 8a: Find a case tool and a platform.
Task 8b: Deliver case tool and platform.
Task 8c: Learn to use case tool and platform.

Task 9: Structured Walk Through of the Revised Design

Peer review of the next revision of the MODIS Processing Structure.

Task 9a: Level-1A
Task 9b: Level-1B

MODIS LEVEL-1 PROCESSING SYSTEM PRELIMINARY DESIGN

DATE : October 19, 1990

KEY:

△ Completion Date

MILESTONES

- Structured Walkthrough of Existing Diagrams
- Define Functional Requirements
- Define Data Definitions
- Define Data and Control Items
- Determine EOSDIS/MODIS Inconsistencies
- Redefine MODIS Structured Diagrams
- Add Information to Data Dictionary
- Generate Event List
- State Transaction Diagram
- Revisit Event List and Transaction Diagram
- Determine Types of Storage Items
- Select Record Fields
- Find a Case Tool and Platform
- Deliver Case Tool and Platform
- Learn to Use Case Tool and Platform
- Structured Walkthrough of the Revised Design